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The Effect of Compaction on Urease Enzyme Activity, Carbon Dioxide Evaluation and Nitrogen Mineralisation

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Abstract: The effects of compaction on urease enzyme activity, carbon dioxide evaluation and nitrogen mineralisation of urea-treated and untreated soils were investigated.

Soils were compacted at compaction levels of 0 kgcm^{-2}, 2 kgcm^{-2} and 4 kgcm^{-2} and incubated for 28 days. The changes in urease enzyme activity, CO_2 evaluation and nitrogen mineralization were determined during incubation periods.

Urease enzyme activity was decreased significantly ($P<0.05$) in all samples, but it was observed that there was a negative effect of compaction on urease enzyme activity and CO_2 evaluation in urea-treated soils.

Depending on incubation peroids, urea-treated soils had 5 times more NH_4^+-N and 4 times more NO_3^--N than untreated soils. Furthermore, compaction induced mitrification in both groups ($P<0.05$).

Key Words: Compaction, urease enzyme activity, carbon dioxide evaluation, nitrogen mineralisation

Toprak Sıkışmasının Üreaz Enzim Aktivitesi, Toprak Solunumu ve Azot Mineralizasyonu Üzerine Etkisi

Özet: Bu araştırmada, toprak sıkışmasının üre ilave edilen ve edilmeyen toprak örneklerinin üreaz enzim aktivitesi, karbondioksit (CO_2) çıkışı ve azot mineralizasyonu üzerine etkisi araştırılmıştır.

Üre ilave edilen ve edilmeyen toprak örnekleri, 0 kgcm^{-2}, 2 kgcm^{-2} ve 4 kgcm^{-2} lik basınçlarla sıkıştırılarak 28 günlük inkübasyona tabi tutulmuşlardır. İnkübasyon süresince örneklerin üreaz enzim aktivitesi, CO_2 çıkışı ve azot mineralizasyonundaki değişimler belirlenmiştir.

Elde edilen sonuçlara göre, üreaz enzim aktivitesi bütün topraklarda önemli derecede azalma göstermiştir ($P>0.05$). Ancak üre ilave edilen topraklarda toprak sıkışmasının üreaz enzim aktivitesi ve CO_2 çıkışı üzerine olan olumsuz etkisi üre ilave edilmeyen topraklara göre daha az bulunmuştur.

İnkübasyon süresine bağlı olarak üre ilave edilmiş topraklarda üre ilave edilmemişe göre yaklaşık 5 kat fazla NH_4^+-N'u ve 4 kat fazla NO_3^--N'u belirlenmiş olup, her iki basınç uygulamasında da nitrifikasyon olayı önemli ölçüde engellenmiştir ($P<0.05$).

Anahtar Sözcükler: Toprak sıkışması, üreaz enzim aktivitesi, karbondioksit çıkışı, azot mineralizasyonu.

Introduction

Compacting of soil may cause problems by changing the porosity in the soil. Since this has effects on biological activity as well as on the physical properties of the soil, the growth of plants and roots may be negatively influenced (1, 2).

Studies concerning aeration characteristics of soil and its effects on growth of plants are mostly concentrated on the composition of air in the soil. The composition of soil air is much different from the of atmospheric air, and its character depends on the biology of the soil. In addition, compacting humidity and soil layer thickness also influence the air content of soil.

Many authors have researched air composition in soil to determine the effects of air characteristics and their role in the growth of plants. However, data about the effects of soil air and the effect of soil/air on microbial activity are scarce.

Soil enzymes are divided into two groups, endo- and ecto-enzymes, according to whether functioning is intracellular or extracellular. Enzymes with activity in the soil are produced by micro-organisms for degradation of organic substances, and these enzymes are adsorbed by soil colloids. They also express activity according to environmental conditions.

Research in Turkey is mainly concerned with enzymes in the hydrolyse group. These enzymes are urea, phosphatase and amylase groups. They are effective in the conversion of nitrogen, phosphorus and sulphur. Date to the effects of pressure on microbial and biochemical parameters, the pave and water diffusion ratio, water infiltration and soil porosity change so that the cycle of nutrient substances is significantly affected (3).

Generally, have studies revealed that low oxygen concentration (2-5%) and low air-filled porosity (<10%) decrease aerobic microbial activity (4).

Studies on soil aeration emphasise the importance of balance between soil, air and water and aerobic and anaerobic microbial activity. Aerobic microbial activity increases when the water content in the soil reaches a level at which water exchanges with air at three levels of oxygen diffusion and availability is limited. At the highest humidity, microbial transpiration, nitrification and mineralisation all reach a maximum. This study aims to determine the effect of soil compaction on urease enzyme activity, soil respiration, and nitrate mineralisation.

Materials and Methods

The soil sample used in this study was obtained from the experimental field at the Ankara University Agricultural Faculty within 0-20 cm of the surface.

Incubation trial

Three different pressures were applied to soils with and without 10% urea to determine the effects on urease enzyme activity, CO_2 precipititation and nitrification. This incubation trial was performed three times at 4 incubation periods, 1, 7, 14 and 28 days, according to pattern of random parcels.

Pressures of 2 kg/cm^2 and 4 kg/cm^2 were applied to a 50 g soil sample with and without 10% percent urea in moisture caps of 100 cm^3 volume.

Table 1. Physical and chemical properties of the soil samples.

Sand, %	26
Loam, %	42
Clay, %	32
Texture class	CL
Field capacity, %	26.1
Witing point, %	12.2
pH	7.88
EC, dS m^{-1}	0.166
Organic matter, %	1.03
Carbonates, %	7.26

During the incubation trial, soil samples were humidified up to 70% percent of field capacity, and humidity was kept constant and measured regularly.

Incubated samples were kept in 28±1°C temperature due to microorganism activity. At the end of each incubation period, urease enzyme activity, CO_2, and NH_4^+-N and NO_3^--N were detected in incubated soil samples.

The soil samples were passed through a 2mm sieve and dried and, humidity was determined gravimatically. The pH of the soil and its electrical conductivity (EC) at 1/2.5 soil water suspension and field capacity and wilting point were obtained according to Richard (5), organic material by the modified Walkley-Black method (6), total nitrogen by the Kjeldahl method (7), grain size distribution by the Bouyoucos method (8), and % carbonate according to Çağlar (9).

At the end of the incubation period, urease activity was determined according to Hoffman and Ticher (10), CO_2 evaluation according to Isermayer (11) and NH_4^+-N and NO_3^--N according to Bremmer (7).

Minitab and Mstat computer programs were used for statistical analyses. Some physical and chemical properties of the soil samples are given in Table 1.

Results and discussion

The effect of compaction on urease enzyme activity

Urease enzyme activity in soils with pressures of 0, 2 and kg/cm^2 (with and without 10% urea) are presented in Table 2.

Table 2. The effect of compaction on urease enzyme activity in soils with and without 10% urea (mg N/100 soil).

Time		Soil		Soil	+ % 10	Urea
Day	Control	2 kgcm^{-2}	4 kgcm^{-2}	Control	2 kgcm^{-2}	4 kgcm^{-2}
1	34.33 Aa	5.33 Ab	0.00Ac	58.97 Aa	7.98Ab	1.33Ac
7	32.70Ba	2.90Bb	0.00Ac	55.97Ba	5.83Bb	0.00Bc
14	30.30Ca	0.00Cb	0.00Ab	52.57Ca	1.03Cb	0.00Bb
28	28.73Da	0.00Cb	0.00Ab	49.00Da	0.58Cb	0.00Bb
LSD (P<0.05) = 0.83		LSD (P<0.05) = 1.13				

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Pressure significantly affected urease enzyme activity in soils without urease. As seen in Table 2, as incubation period increases, urease enzyme activity significantly decreases (P<0.05).

Urease enzyme activity in control samples was 34.33 on the first day, decreasing to 28.73 mgN/100g soil by the and of the 28th day. However, when 2 kg/cm^2 of pressure was applied, no urease activity was seen on the 14th and 28th days of incubation.

Moreover, 4 kg/cm^2 caused no urease enzyme activity during the entire period of incubation.

The changes in urease activity in the soil samples with and without 10% urea depending on 49 mg N/100 g soil level on the 28th day of incubation. Urease enzyme activity in the first, second, and third incubation periods changed significantly when a pressure of 2 kg/cm^2 was applied to the soil. This change was insignificant at the 4th incubation period. When a pressure of 4 kg/cm^2 was applied, there was no urease enzyme activity on the first day of in incubation. However, in soil amended with 10% urea, 1.33 mg N/100 g soil urease enzyme activity was determined.

Dick et al. (4), attempting to determine the effect of pressure on enzyme activity, found that the activity of the phosphatase enzyme, which is a hydrolase enzyme, as well as dehydrogenase activity, decreased 41-75%. We were unable to find any other studies on urease activity, yet the urease enzyme belongs to the hydrolase enzyme group. These findings appear to be consistent with the results of the present study.

The compaction effects on soil respiration

Soil respiration was observed by CO_2 formation processes in 24 hours. In the urea-amended and unamended soil samples, CO_2 evaluation values, determined at three different applied pressures, are shown in Table 3.

Table 3. The effect of compaction on soil respiration with and without 10% urea (mgCO_2/24 h)

Time		Soil		Soil	+ %10 Urea	
Day	Control	2 kgcm^{-2}	4 kgcm^{-2}	Control	2 kgcm^{-2}	4 kgcm^{-2}
1	8.43Aa	3.33Ab	2.20Ac	6.52Aa	3.47Ab	1.95Ac
7	7.47Ba	2.50Bb	0.95Bc	5.80Ba	2.98Ab	1.75Bc
14	6.46Ca	2.10Bb	0.11Cc	4.48Ca	2.47Bb	0.33Cc
28	5.23Da	0.42Cb	0.00Cb	3.97Da	0.75Cb	0.10Cc
LSD (P<0.05) = 0.60		LSD (P<0.05) = 0.51				

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According to Table 3, depending on incubation time and increasing pressure levels, the differences between CO_2 evaluation values of 10% urea added soil samples were found statistically significant (P<0.05).

On the first and 28th days of incubation, CO_2 evaluation rate in the urea non added control soils were determined 8.43 and 5.23 mg/CO_2 respectively.

All incubation times important for decreasing CO_2 were observed between control samples and CO_2 by the use of two different pressure levels. In addition, CO_2 values were different for each pressure level, and when the pressure increased, the CO_2 balance was significantly decreased (P<0.05).

The CO_2 value of soil samples was decreased to zero with the application (on the final day of incubation) of 4 kg/cm^2 pressure.

Depending on incubation time and pressure levels, in comparison to the urease activity of controls, differences in the urea-treated soil samples were found to be statistically significant (P<0.05).

The urease acticity of control samples was decreased to 58.97 on the first day of incubation and to 49 mg N/100 g soil on the 28th day of incubation, respectively. When a pressure of 2 kg/cm^2 was applied on the soil, the changes in urease enzyme activity in the first, second and third periods of incubation were significant. In the fourth incubation period, there was no difference statistically (P<0.05). When 4 kg/cm^2 of pressure was applied on the soil on the first day of incubation, low enzyme activity was observed. In other incubation terms, no urease enzyme activity was detected.

In the 10% urea samples, the effects of pressure on the soil were prevented. In the soil samples on the first day of incubation with a pressure of 4 kg/cm^2, there was no urease enzyme activity. Urease enzyme activity was determined to be 1.33 mg N/100 g soil in the urea-treated samples.

Dick et al. (4) determined the effects of pressure on enzyme activity. They found that the activities of phosphatase and dehydrogenase (which belongs to the hydrolase group) decreased to 41-75%.

The effects of compaction on nitrogen mineralisation

Depending on increased pressure and incubation time, NH_4^+-N changed in soil samples with 10% urea. In contral smaples, there was 110.12 mg/kg NH_4^+-N on the 28th day. In soils where a pressure of 2 kg/cm^2 was applied there was 101 and 25.31 mg/kg NH_4^+-N on the 1st and 28th days of incubation (Table 4). During incubation, mineralisation of NH_4^+-N in control samples increased and, following ammonification, formation of NO_3^--N continued. In soils where 2 and 4 kg/cm^2 of pressure was applied, mineralisation of NH_4^+-N and formation of NO_3^--N following ammonification significantly decreased (P<0.05).

Table 4. The effects of compaction on soils NH_4^+-N with and without 10% urea (mg/kg)

Time		Soil		Soil	+ %10 Urea	
Day	Control	2 $kgcm^{-2}$	4 $kgcm^{-2}$	Control	2 $kgcm^{-2}$	4 $kgcm^{-2}$
1	111.12Aa	101.00Ab	94.00Ac	601.67Aa	590.33Ab	572.33Ac
7	70.64Bc	75.15Bb	84.78Ba	435.70Bc	542.33Ba	530.00Bb
14	50.87Cc	65.85Cb	77.20Ca	310.00Cc	486.00Cb	501.73Ca
28	15.18Dc	35.31Db	50.37Da	156.42Dc	279.73Db	292.03Da
LSD (P<0.05) = 1.638		LSD (P<0.05) = 9.96				

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In the control samples where no pressure was applied and no urea was added, NH_4^+-N was 39.27 mg/kg and 90.32 mg/kg on the 1st and 28th day, respectively (Table 5).

Table 5. The effects of compaction on soils NO_3^--N with and without 10% urea (mg/kg)

Time		Soil		Soil	+ %10 Urea	
Day	Control	2 $kgcm^{-2}$	4 $kgcm^{-2}$	Control	2 $kgcm^{-2}$	4 $kgcm^{-2}$
1	39.27Da	30.70Cb	30.99Db	110.67Dc	142.33Ca	130.33Bb
7	65.09Ca	50.29Ab	45.57Ac	229.67Cb	261.89Aa	162.88Ac
14	94.88Aa	45.21Bb	40.38Bc	252.33Ba	173.33Bb	103.77Cc
28	90.32Ba	38.55Cb	30.99Cc	405.23Aa	90.39Db	70.12Dc
LSD (P<0.05) = 1.68		LSD (P<0.05) = 5.05				

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In control samples, NO_3^--N gradually increased, reaching the highest level at the 14th day (P<0.05). In 2 and 4 kg/cm^2 pressure applied soil samples NH_4^+ increased on the 7th incubation day, and with time significantly decreased (P<0.05).

On the 1st day of nicubation, the differences between NH_4^+ amounts in soils with different applied pressures were not significant. In later days, pressure was found to be significantly increased as the NH_4^+ amount decreased (P<0.05).

Depending on incubation time, in control samples and in urea-treated soils with two different applied pressures, the decrease in NH_4^+-N level was significant (P<0.05) (Table 4). In control samples, 601.67 mg/kg and 156.42 mg/kg NH_4^+-N was found on the 1st and 28th days of incubation, respectively. In control samples, NH_4^+-N was highest on the first incubation day. However, NH_4^+-N was highest after the 7th incubation day in soil samples where 4 kg/cm^2 pressure was applied (excluding the 70th day). As in soils without urea, in the urea-treated soils, pressure slowed down the mineralisation of NH_4^+-N. In urea-treated control samples, 110.67 mg/kg and 405.23 mg/kg NO_3^--N was found on the 1st and 28th day of incubation, respectively (Table 5). On the 1st incubation day, control samples had lower amounts of NO_3^--N with respect to soils under different pressure regimes. After 7th the day of incubation following ammonification, nitrification had started, and over time, the level of NO_3^--N increased in control samples (P<0.05). On the 7th day, in soils under 2 and 4 kg/cm^2 pressure regime. NO_3^--N level reached a peak, but later on decreased significantly (P<0.05). On the 28th day of incubation, the NO_3^--N level was approximately seven times lower than in the control group. The NO_3^--N level in the control samples and pressure-regime soils changed significantly (P<0.05).

In the urea-treated soils, the NO_3^--N level was 4 times higher than in the non-urea-treated soils. On the first day of incubation the NO_3^- N level invaded under 2 different pressure regimes, but later on it gradually decreased and nitrification stopped. At the same time, there was significant N loss in compacted soil samples. In all control groups, nitrogen loss in gaseous form was 21.15%, and under 2 kg/cm^2 and 4 kg/cm^2 pressure this loss was 49.48% and 48.46% in the urea-treated and 28.84%, 43.92%, 34.90% in the untreated soil samples, subsequently.

As a result, we can suggest that depending on both NH_4^+-N and NO_3^--N amounts, nitrification significantly decreased in compacted soils. The same results also have been reported by Bakken et al. (12). The authors stated that in compacted soils denitification increased, and nitrogen loss was 2-4 times higher than controls.

Torbent and Wood (13) reported that nigtrogen loss in compacted soils depended on water-filled pores, the diameter of the pores and structure. Masse et al. (14) found that in compacted soils, plants utilised much less nitrogen than control samples.

Landina and Klavenskaya (1) stated that nitrogen fixation was affected by texture of soil, and that in loose soils nitrogen fixation was 5 times higher than in compacted soils. According to the authors, nitrogen fixation as well as maintenance increases in 26 days in loose soils and 15 days in compacted soils.

The pressure of the soil may affect microbial activity depending on certain physical properties such as decreased total porosity, air content, water infiltration rate and saturation in hydraulic conductivity. Soil pressure is associated with a decrease in nitrogen fixation by the microbial population (1), nitrification rate, and free-living micro-organisms (15). The effects of pressure on the biological and chemical properties of the soil are also related to limited root growth in compacted soil. According to Dick et al. (4), changes in the physical properties of compacted soils and the decrease in root growth affect microbial activity.

In different climates and different kinds of soils, pressure causes changes in biological properties. Smith and Waas (16) have shown negative and positive effects of pressure on the physical and chemical parameters of five different soil textures.

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